Total Maximum Daily Loads (TMDLs) Steilacoom Lake and Chambers Creek

prepared by

U.S. Environmental Protection Agency

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Watershed:	***Chambers-Clover Basin (WRIA 12)***
Uses Affected:	***Aesthetic Enjoyment***
	Aquatic Life
Impairment:	***Eutrophication***
	Toxicity
Pollutants:	***Phosphorus***
	Copper
Sources Considered:	***Clover Creek***
	Ponce de Leon Creek
	Steilacoom Lake
Waters Impacted:	***Steilacoom Lake - WA-12-9080 (New ID # 425LMS)***
	Chambers Creek- WA-12-1110 (New ID # DO71CI)

Introduction

Section 303(d) of the federal Clean Water Act (CWA) mandates that the state establish Total Maximum Daily Loads (TMDLs) for surface waters that do not meet standards after application of technology-based pollution controls. The U.S. Environmental Protection Agency (EPA) has promulgated regulations (40 CFR 130) and developed guidance (EPA, 1991) for establishing TMDLs. In response to a lawsuit challenging the rate of TMDL development in Washington, EPA, the Washington Department of Ecology (Ecology) and plaintiffs entered in a settlement agreement which included a schedule for establishing TMDLs. EPA is establishing this TMDL consistent with Washington State water quality standards to assist Ecology in achieving the agreed upon schedule.

Under the Clean Water Act, every state must establish and maintain water quality standards designed to protect, restore, and preserve the quality of waters in the state. These standards consist of: narrative criteria that include designated uses; specific chemical and biological criteria necessary for protection of designated uses; and anti-degradation provisions. When a

lake, river, or stream fails to meet water quality standards after application of required technology-based controls, section 303(d) of the CWA requires that the state place the water body on a list of "impaired" water bodies and prepare an analysis called a **Total Maximum Daily Load (TMDL)**.

The goal of a TMDL is to ensure the listed water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. It determines the amount of a given pollutant which can be discharged to the water body with standards still being met, the **loading capacity,** and allocates that load among the various sources. If the pollutant comes from a discrete source (referred to as a **point source**) such as an industrial facility's discharge pipe, that facility's share of the loading capacity is called a **wasteload allocation**. If it comes from a diffuse source (referred to as a **non-point source**) such as a farm, that facility's share is called a **load allocation**.

The TMDL must also consider seasonal variations and include a **margin of safety** that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. The sum of the individual allocations and the margin of safety must be equal to or less than the loading capacity.

Background

Steilacoom Lake was created in 1852 when a dam was constructed across Chambers Creek, inundating a wetland. Steilacoom Lake currently covers about 53 acres and is contained within the City of Lakewood. Steilacoom Lake is shallow with a mean depth of 11 feet and a maximum depth of 20 feet. The ratio of the watershed to lake surface area is high (167:1). Approximately 35 percent of the watershed is urbanized. The lake has two tributaries: Clover Creek and Ponce de Leon Creek. The Clover Creek watershed drains areas in the City of Lakewood, unincorporated Pierce County, McChord Air Force Base, and Fort Lewis Army Base. The Ponce de Leon watershed drains areas only within the City of Lakewood. In addition, the City's stormwater runoff enters the lake through several drains along the shoreline. The lake outlet is to Chambers Creek, which flows four miles before draining into Puget Sound.

Steilacoom Lake is heavily used by lakeshore residents for a variety of recreational purposes. The lake is regarded as an amenity by the local community, and the property values around the lake are influenced by its condition. The water flowing from the lake into Chambers Creek is used by two Washington State Department of Fish and Wildlife Hatcheries just downstream: Chambers Creek Hatchery and South Tacoma Hatchery. A third hatchery is located near the mouth of the Chambers Creek (Bay) which flows into Puget Sound. Coho and chinook salmon are known to utilize Chambers Creek for spawning, rearing and migration. Anadromous fish use the lake for migration. Resident fish are mostly warm water species, with largemouth bass being the most abundant (40%) of the resident fish.

Steilacoom Lake is highly productive (i.e., has a large amount of nutrients such as nitrogen and phosphorus), creating problems that include dense beds of aquatic plants, algal blooms, and low

water clarity. The high productivity is primarily due to the lake's shallowness, nutrient-rich sediment, and a high loading of nutrients from the watershed.

A group comprised primarily of residents living near the lake formed the Steilacoom Lake Improvement Club. Since the 1950s, this club has attempted to manage the algae and aquatic plants in the lake through the use of chemical herbicides. A variety of herbicides have been applied, but copper sulfate has been used most frequently because of its low cost and high effectiveness at controlling algal blooms and swimmer's itch parasites. The state's water quality criteria for copper is exceeded in the Steilacoom Lake and downstream in Chambers Creek, when copper sulfate is applied to the Lake as a herbicide. Under the provisions of Chapter 90.48 Revised Code of Washington (RCW) and Washington Administrative Code (WAC) 173-201A-110, Ecology has issued short-term modifications to the water quality standards for Steilacoom Lake for these applications.

In 1996, a diagnostic and feasibility study of restoration alternatives for Steilacoom Lake was published (KCM, 1996). The goal of the study was to:

> determine the physical, chemical, and biological condition of Steilacoom Lake and to develop a lake management plan which shall develop and include feasible long-term solutions for the weed, algae, sediment and water quality problems of Steilacoom Lake, or in the alternative, determine that there are no feasible long-term solutions to some or all of the weed, algae, sediment and water quality problems of Steilacoom Lake.

The study conducted water quality and limnological tests of Steilacoom Lake and the watershed. The study presented 10 management scenarios for restoration of the lake. The management scenarios were ranked based on their potential to maximize the beneficial uses of the lake while reducing the environmental impact on non-targeted organisms.

Since the publication of the restoration study, no management plan has yet been developed. Grant funding for any of alternatives presented has not been applied for. Ecology has continued to allow application of herbicides by issuing short-term modification to the water quality standards.

Water Quality Conditions

The most comprehensive study of Steilacoom Lake and its tributaries came from KCM (1996). The study collected extensive information on the water quality and limnological characteristics of the lake. The study also developed water and nutrient budgets and modeled the lake response to nutrient inputs. The study verified that Steilacoom Lake is eutrophic and phosphorus is the nutrient limiting aquatic plant growth. The shallowness of the lake, runoff from the developed watershed, and rich organic sediments create a physical and chemical environment that can support large algal blooms and nuisance densities of aquatic plants that cover over 80 percent of the lake bottom. Dense plant stands have restricted swimming, boating, and fishing, and have

decreased water quality and fish habitat. Blue-green algal blooms in Steilacoom Lake were declared toxic by the Tacoma-Pierce County Health Department in 1992, 1994 and 1995.

Another extensive study was conducted by the U.S. Geological Survey (USGS) in 1991-1992 on the Clover Creek watershed, the largest tributary to Lake Steilacoom (McCarthy, 1996). The study describes the spatial and temporal water quality characteristics of Clover Creek and its tributaries, and provides information of the influence of land use and other watershed characteristics on storm water runoff.

Due to the repeated application of copper-based herbicide applications, Steilacoom Lake has developed high levels of copper in the sediments. There are no other known nor permitted sources of copper discharging upstream or directly into Steilacoom Lake. In 1990, Ecology conducted a study of copper in the sediments (Bennett and Cubbage, 1992). Sediment copper concentrations averaged 710 mg/Kg with a range of 180 to 1,100 mg/Kg. Bioassays tests (toxicity testing using Hyalella and Hexagenia) also documented that the sediment exhibited toxicity (Bennett and Cubbage, 1992). State water quality standards do not yet contain chemical specific criteria for fresh water sediment. However, to put these concentrations in context, the Province of Ontario, Canada, has used a copper level of 110 mg/Kg as a "severe effects" threshold, and the Washington State marine sediment quality standard is 390 mg/Kg. Copper concentrations in Steilacoom Lake sediment are among the highest in Washington state.

Ecology also collected dissolved copper concentrations at a number of locations in Lake Steilacoom and Chambers Creek for up to 36 days following a permitted herbicide application (Serdar, 1997). These data showed that dissolved copper concentrations exceeded both acute and chronic criteria in Chambers Creek for at least 15 days following the application, and concentrations at the Steilacoom Lake dam were equal to the chronic criterion (for protection of aquatic life) for 36 days post-treatment.
The Washington Department of Ecology included Chambers Creek on the 1998 303(d) list for exceeding the water quality standard for copper. Steilacoom Lake is included on the 303(d) list for not meeting standards for phosphorus and sediment bioassay. This TMDL study addresses dissolved copper concentrations in Chambers Creek and phosphorus loading to Steilacoom Lake. The associated problem with copper contamination in the Lake Steilacoom sediments is not addressed by this TMDL. Nonetheless, it is anticipated that by setting copper allocations to Chambers Creek, the copper loading to the Lake Steilacoom sediments will be reduced.

Applicable Criteria

Within the state of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). Authority to adopt rules, regulations, and standards as are necessary to protect the environment is vested with the Department of Ecology. Under the federal Clean Water Act, the EPA Regional Administrator must approve the water quality standards adopted by the State (Section 303(c)(3)). Through adoption of these water quality standards, Washington has designated certain characteristic uses to be protected and the criteria necessary to protect these uses [Washington Administrative Code (WAC), Chapter 173-201A).

Water quality standard are periodically reviewed and modified. The most recent modification of state standards were adopted in November 1997.

This TMDL is designed to address impairments of characteristic uses caused by eutrophication and the application of herbicides used to control aquatic plant growth associated with eutrophication. The characteristic uses designated for protection of lakes in Washington's water quality standards are as follows:

"Characteristic uses. Characteristic uses shall include, but not be limited to, the following:

(i) Water supply (domestic, industrial, agricultural).

(ii) Stock watering.

(iii) Fish and shellfish:

Salmonid migration, rearing, spawning, and harvesting.

Other fish migration, rearing, spawning, and harvesting.

Clam and mussel rearing, spawning, and harvesting.

Crayfish rearing, spawning, and harvesting.

(iv) Wildlife habitat.

(v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).

(vi) Commerce and navigation."

[WAC 173-201A-030(5)(b)]

For phosphorus, which is causing eutrophication of Steilacoom Lake:

"Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste."

[WAC 173-201A-030(5)(c)(viii)]

The water quality standards set the phosphorus action level for Lake Steilacoom at 20 ug/L [WAC 173-201A-030(6)]. The action level is a criterion where additional study and activities are initiated to protect the lake. If this value is exceeded, additional analysis is required to identify a lake specific criterion that is protective of designated characteristic uses. KCM (1996) conducted a study of the lake and concluded that an in-lake phosphorus concentration of 20 ug/L is needed to prevent eutrophication based on the widely used phosphorus loading response model developed by Dillon and Rigler (1974) and Vollenweider (1975). Both the state action level and KCM (1996) identified the maximum concentration of phosphorus required to prevent eutrophication in Steilacoom Lake as 20 ug/L. These evaluations represent the best available information about pollutants loading levels necessary to protect designated characteristic use and associated water quality standards.

In addition to phosphorus loading to Steilacoom Lake from human activities, there are also contributions from natural factors, or natural background conditions. When water quality is limited due to natural conditions, the water quality standards define the loading level needed to protect uses to be those natural background conditions.

> *"Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria."*
>
> [WAC 173-201A-070(2)]

Water quality standards applicable to copper include the following:

> *"Toxic, radioactive, or deleterious material concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department."*
>
> [WAC 173-201A-030(5)(c)(vii)]

"(1) Toxic substances shall not be introduced above natural background levels in waters of the state which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department.

(2) The department shall employ or require chemical testing, acute and chronic toxicity testing, and biological assessments, as appropriate, to evaluate compliance with subsection (1) of this section and to ensure that aquatic communities and the existing and characteristic beneficial uses of waters are being fully protected.

(3) The following criteria shall be applied to all surface waters of the state of Washington for the protection of aquatic life. The department may revise the following criteria on a state-wide or water body-specific basis as needed to protect aquatic life occurring in waters of the state and to increase the technical accuracy of the criteria being applied. The department shall formally adopt any appropriate revised criteria as part of this chapter in accordance with the provisions established in chapter 34.05 RCW, the Administrative Procedure Act. The department shall ensure there are early opportunities for public review and comment on proposals to develop revised criteria. Values are ug/L for all substances except Ammonia and Chloride which are mg/L:

The state has adopted the following water quality standards for copper which were developed by the EPA (Quality Criteria for Water, 1986) for the protection of aquatic life, including fish;

Freshwater Acute Copper Concentration £ (0.960)(e$^{(0.9422[\ln(\text{hardness})] - 1.464)}$)

A one-hour average not to be exceeded more than once every three years on the average."

Freshwater Chronic Copper Concentration £ (0.960)($e^{(0.8545[ln(hardness)] -1.465)}$)
A 4-day average concentration not to be exceeded more than once every three years on the average."

[WAC 173-201A-040)]

Determining the allocations of the TMDL require the use of critical conditions. The water quality standards define the instream flow where critical conditions occur:

> ***"Critical condition"*** *is when the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or characteristic water uses. For steady–state discharges to riverine systems the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the department."*
>
> *[WAC 173-201A-020]*

Loading Capacity Analysis

For Phosphorus

KCM (1996) determined the maximum phosphorus loading required to prevent the eutrophication of Steilacoom Lake with the widely used lake response model developed by Dillon and Rigler (1974) and Vollenweider (1975). The model was used to estimate the phosphorus loading that would maintain an in-lake concentration of 20 ug/L. The resulting phosphorus load to prevent eutrophication is estimated at 3.1 kg/day (6.8 lbs/day). This represents the loading capacity. The KCM (1996) study measured the total loading to the lake in 1994-1995 to be 4.7 kg/day (10.4 lbs/day). Therefore, phosphorus loading to Steilacoom lake must be reduced by 35% (3.6 lbs/day) in order to prevent eutrophication and fully support the designated uses.

For Copper

Development of a TMDL involves defining the critical conditions for the stream and determining the level of pollutant loads that can be assimilated without violating water quality standards or impairing designated uses. Washington state water quality standards (Chapter 173-201A-020) define the critical conditions for instream flow as the annual 7-day low flow with a recurrence interval of 10 years (7Q10). These low flow conditions are used in the analyses for determining limitations for discharge of pollutants. A part of the margin of safety (in the

pollutant loading analyses) is represented inherently by use of the low (7Q10) flow for critical conditions.

To compute the critical low flow conditions for the outflow from Steilacoom Lake into Chambers Creek, data were taken from the USGS continuous flow gauging station (#12090500) on Clover Creek near the inflow to Steilacoom Lake and from the water budget of KCM (1996). There are 10 years of data recorded at the USGS flow gauge in Clover Creek with many days where the flow was below the detection level. Using the detection level for those days, the critical low (7Q10) flow for Clover Creek is 0.1 cfs. The Steilacoom Lake water balance observed in 1994 and 1995 shows that Chambers Creek has 2.87 times more flow than Clover Creek. Applying this ratio to the Clover Creek critical (7Q10) low flow provides an estimated critical low flow in Chambers Creek at the outlet to the lake of 0.29 cfs.

To determine the maximum copper load that Chambers Creek can assimilate without exceeding the water quality standard, the stream hardness must be determined. Samples collected by Ecology show the hardness ranges between 43.9 to 51.1 mg/L $CaCO_3$ (Serdar, 1997). The lower 5^{th} percentile of hardness values measured (45.9 mg/L $CaCO_3$) was used to calculate the water quality standard for copper. Using this conservative hardness value contributes to a margin of safety which is necessary to address uncertainty and variability in ambient conditions and assumptions of the TMDL analyses. The acute and chronic dissolved copper criterion were calculated to be 8.2 and 5.8 ug/L, respectively. The more restrictive copper standard is the chronic criterion for protection of aquatic life. Applying the estimated critical low flow **(**0.29 cfs) to the chronic copper criterion results in a maximum loading capacity from Steilacoom Lake of 0.009 lbs/day [(.0058 mg/l)(0.29 cfs)(0.646 mgd/cfs)(8.34 conversion factor) = 0.009 lbs/day].

The principle discharges into Chambers Creek downstream of the dam are the three state fish hatcheries. These facilities reported that they do not use copper-based chemicals in hatchery operations. Historically, hatcheries did use copper containing chemicals such as malachite green and copper sulfate. Accordingly, no allocation for discharge of copper to Chambers Creek is being provided to these dischargers.

TMDL Allocations

For Phosphorus:

In order to reduce the phosphorus loading to levels which do not exceed the assimilative capacity of Steilacoom Lake, an inventory of pollutant sources is needed. KCM (1996) provided such an inventory from monitoring (Table 1). This inventory did not distribute the measured loads to the relevant jurisdictions with responsibility for controlling the pollutant loads. Loading was determined at locations where the United States Geologic Service (USGS) had established gauging stations. The inventory documents that over 80 percent of the total phosphorus loading to the Lake comes from Ponce de Leon Creek and Clover Creek. KCM (1996) reports that most

of the phosphorus in Ponce de Leon Creek appears to come from the vicinity of the Lakewood Mall.

Of all the sources of phosphorus identified, two jurisdictions have existing NPDES permits that may be conditioned to control the pollution: McChord Air Force Base and Pierce County. These jurisdictions are permitted to discharge stormwater to Clover Creek. A small area of the Fort Lewis Army Base falls within the watershed, but has no identified or permitted stormwater discharges into the Steilacoom Lake drainage. This area of Fort Lewis is in an undeveloped area of the base and contains a natural wetland that serves as the headwater to Spanaway Creek.

Even if all of the phosphorus was removed from Clover Creek, a reduction in other phosphorus sources would be needed to achieve the TMDL goal. The remainder of the sources are located in the City of Lakewood, which will be required by federal municipal Phase II stormwater regulations to obtain a NPDES permit to discharge stormwater.

Table 1. Summary of Steilacoom Lake Phosphorus Budget from May 1994 to April 1995

Source of Loading	**Phosphorus Load** (kg/yr)	**Phosphorus Load** (lbs/day)	**Percent of Total**
Precipitation	50	0.30	3%
Shoreline Runoff	55	0.33	3%
Ponce de Leon Creek	811	4.89	47%
Clover Creek	592	3.57	34%
Groundwater Inflow*	49	0.30	3%
Waterfowl*	112	0.67	6%
Internal Loading (sediment and macrophytes)	60	0.36	3%
Total	1,730	10.42	100%

*Loading from waterfowl and groundwater inflow are directly into the lake.

In order to determine a phosphorus allocation for the two existing stormwater permits, the load from different parts of the Clover Creek watershed must be determined. The phosphorus concentrations and flows measured by McCarthy (1996) at four locations on the creek in 1991 provide the proportional load from the three jurisdictions (Table 2). Since there is not a statistically significant correlation between flow and phosphorus concentrations (McCarthy, 1996), the proportional loads were calculated based on independent monthly averages of flows and phosphorus concentrations. These data were reviewed to determine the period during which they were sufficient to calculate loads at each of these stations.

Data collected in March 1991 by McCarthy (1996) was used for calculating loads at stations 430, 480, 500, and 602. Since no data were collected by McCarthy (1996) at station 460 during March 1991, the load was estimated. The estimate was made by comparing the relative flow at stations 460 and 480 during February 1992. The flow at station 460 was found to be 3.8 times larger than the flow at station 480. Applying this ratio to the phosphorus load of 18.3 at station 380 in March 1991 results in an estimated load of 69.8 at station 360.

Table 2. Phosphorus Loads at Different Locations on Clover Creek from March 1991 (adapted from McCarthy, 1996).

Station ID	Station Location	Phosphorus Load (kg/mo)	Phosphorus Load (lbs/day)	Percent of Clover Creek Load Entering Steilacoom Lake
430	Clover Creek Upstream of McCord AFB	142	10.1	54%
460	Spanaway Creek Upstream of McCord AFB	69.8	5.0	27%
480	Morey Creek Upstream of McCord AFB	18.3	1.3	7%
500	Clover Creek Downstream of McChord AFB	250	17.7	96%
602	Clover Creek near the Inflow to Steilacoom Lake	261	18.5	100%

Dividing total phosphorus loading to Clover Creek according to the percentage of land controlled by jurisdictions within the watershed produces the following ratios for contribution of phosphorus: Pierce County at 75%, Fort Lewis Army Base at 13%, McChord Air Force Base at 8%, and the City of Lakewood at 4%. The relative phosphorus loads between Pierce County and Fort Lewis in Spanaway Creek were derived by the proportion of land area for each.

In order to establish load and wasteload allocations, phosphorus loading from both non-anthropogenic (background) and anthropogenic causes must be estimated for the creeks in the Steilacoom Lake watershed. To determine the pre-disturbance (non-anthropogenic) phosphorus loading, the pre-disturbance vegetation was taken from the General Land Office Surveys conducted in the 1870's prior to extensive development. The purpose of these surveys was to establish section lines. During these surveys, the size and species of trees along with other vegetation were recorded. For the area of Clover Creek watershed the following description was recorded: "Timber, chiefly fir, cedar and hemlock grown to immense size and is of the finest quality" (GLO, 1870). As a margin of safety, the lower quartile of phosphorus export coefficients found in the literature (Reckhow et al. 1980) for forests (0.019 kg/ha/yr) was applied to the 66.9 square mile Clover Creek watershed area for estimating pre-disturbance phosphorus loading. Using this approach, the phosphorus loading in 1870 is estimated to have been 373 kg/yr (2.2 lbs/day).

The load allocation of 373 kg/year for natural background conditions in Clover Creek was divided according to the area under the control of each jurisdiction within the drainage as shown below:

Clover Creek in Lakewood	5.4 kg/year
Clover Creek in McChord AFB	13.5 kg/year
Clover Creek in Pierce County	219.9 kg/year
Morey and Spanaway Creek	57.7 kg/year
Spanaway Creek in Fort Lewis	76.5 kg/year
	373 kg/year total

Contributions of phosphorus from natural conditions in the remaining part of the Steilacoom Lake watershed are:

Ponce de Leon Creek	18.9 kg/year
Shoreline Runoff	37.8 kg/year

Reducing the phosphorus contribution from Clover Creek to non-anthropogenic background levels will not be sufficient to achieve the loading capacity needed for prevention of eutrophication in Steilacoom Lake. KCM (1996) identified Ponce de Leon Creek as the largest controllable source of phosphorous loading. Therefore, in addition to reducing phosphorous discharges to natural background levels from permitted stormwater outfalls (McChord AFB and Pierce County) into Clover Creek, phosphorus from Ponce de Leon Creek must be reduced by 49% (336 kg/yr) in order to meet the loading capacity.

KCM (1996) suggests several options for reducing the phosphorus in Ponce de Leon Creek. The Ponce de Leon Creek drainage is within the City of Lakewood. Since there is currently no municipal stormwater permit required of the City of Lakewood, actions by this City to reduce phosphorus in the creek would initially be voluntary. However, as stormwater permits are issued in the year 2002, the City of Lakewood would be required to meet the allocations set forth in the TMDL. Alternatively, an NPDES stormwater permit could be issued that included water quality-based effluent limitations at an earlier date.

The final phosphorus allocations for the TMDL are shown in Table 3. These allocations are presented in both yearly loads and daily loads. Table 3.a presents the phosphorus waste load allocations by entity and where they apply. Lake eutrophication is typically managed by controlling annual loading, since the algal response is based on the total amount of phosphorus introduced to the lake over the year. An estimated maximum daily load is presented because of requirements of the CWA. However, annual loading should be used for determining if the waste load allocations for the TMDL are being met.

Table 3: Allocations of Phosphorus from Sources to Steilacoom Lake

Source of Loading	Existing Phosphorus Load		Allocated Phosphorus Load		Reduction Required
	kg/yr	lbs/day	kg/yr	lbs/day	Percent
Precipitation	50	0.30	50	0.30	0%
Shoreline Runoff	55 (37.8)	0.33	55	0.33	0%
Ponce de Leon Creek	811 (18.9)	4.90	413.7	2.50	49%
Clover Creek in Lakewood	23.7 (5.4)	0.14	23.7	0.14	0%
Clover Creek in McChord AFB	47.4(13.5)	0.29	13.5*	0.08	72%
Clover Creek in Pierce Co.	319.7 (219.9)	1.93	219.9*	1.33	31%
Morey Creek and Spanaway Creek in Pierce Co.	124.8 (57.7)	0.75	57.7*	0.35	54%
Spanaway Creek in Fort Lewis Army Base	(76.5)	0.46	76.5	0.46	0%
Groundwater Inflow	(49)	0.30	49	0.30	0%
Waterfowl	(112)	0.67	112	0.67	0%
Internal Loading	(60)	0.36	60	0.36	0%
Total	1,729.1	10.43	1,131	6.82	35%

(value) in parentheses represents the portion of the load allocations for natural conditions

Table 3a: Wasteload Allocations of Phosphorus to Steilacoom Lake

Source of Loading	Allocated Phosphorus Load	
	kg/yr	lbs/day
Stormwater discharges from the *City of Lakewood* into Ponce de Leon Creek	413.7	2.50
Stormwater discharges from *McChord AFB* into Clover Creek	13.5	0.08
Stormwater discharges from *Pierce County* to Clover Creek	219.9	1.33
Stormwater discharges from *Pierce County* to Morey Creek and Spanaway Creek.	57.7	0.35

Phosphorus loading allocations could be distributed differently than as established in this TMDL. These phosphorus loading allocations are established in consideration of first, what is enforceable through the NPDES stormwater permits and second, what is the most feasible action that can be taken by regulatory agencies to implement the TMDL. In its 1991 Guidance for Water Quality-based Decisions: The TMDL Process, EPA states that:

> In order to allocate loads among both non-point and point sources, there must be reasonable assurances that non-point source reduction will in fact be achieved. Where there are not reasonable assurances, under the CWA, the entire load reduction must be assigned to point sources.

It is EPA's position that reasonable assurance is provided when all of the following elements are fulfilled:

- Existing implementation commitments within the watershed are documented, such as currently funded BMPs and other restoration projects, letters of commitment from landowners, local ordinances, etc., and

- Commitment is provided to:

- develop an implementation plan within a specified period of time;
- include a monitoring program in the implementation plan which evaluates both 1) implementation of BMPs and other needed control actions, and 2) trends in relevant water quality parameters;
- seek funding for the implementation plan; and
- the process for revising the TMDL is explained.

EPA acknowledges that local and county government could achieve necessary reductions by addressing ubiquitous sources of phosphorus loading from land use activities within their jurisdiction in the watershed, including direct runoff from residential, commercial and agricultural lands. Since no such plans exist to control phosphorus loading to Steilacoom Lake, the reduction in loads will target permitted sources and reflect natural background levels.

For Copper

As mentioned earlier in this document, the only known discharge of copper into Steilacoom Lake/Chamber Creek is from application of copper-based herbicides. These applications are considered discharges that can be regulated by special use conditions and restrictions established in state or federal permits.

To determine the maximum copper load that can be applied to Steilacoom Lake without exceeding water quality standards in Chambers Creek, the background concentration of copper flowing from the lake must be used as a baseline. To provide a margin of safety, the 90th

percentile of monitored copper values were used as recommended by the Washington State Department of Ecology (1996). Dissolved copper samples were collected at the outlet of Steilacoom Lake by Ecology between 10/96 and 10/97, when no herbicides treatments were made. The results of this monitoring show a range of concentrations from 0.58 to 3.49 ug/L and a 90^{th} percentile concentration of 3.49 ug/L. At critical conditions this represents loading from background equal to 0.0055 lbs/day. Subtracting the loading from background (0.0055 lbs/day) from the loading capacity (.009 lbs/day) leaves 0.0035 lbs/day can be allocated to human activity.

Data collected after the application in 1996 were used to determine the amount of dissolved copper that reaches Chambers Creek in response to herbicide application in Steilacoom Lake. There are little data available to accurately model the complex interactions of the herbicide with the hydrodynamics of the lake and it has not been determined how much of the copper in lake sediment may be re-dissolving into the water column. However, Stumm and Morgan (1981) predicts a very low redissolution of copper and any copper that potentially redisolves was included as part the background concentrations which was measured when herbicides were not applied**.** Therefore, the approach of this TMDL analyses is to assume that the amount of copper load introduced by herbicide application is proportional to the amount of additional copper load received by Chambers Creek at the Steilacoom Lake outfall.

Since flows were not measured in Chambers Creek when copper samples were taken in June 1996, they were estimated from the water balance for June derived by KCM (1996) and the flow measured by the USGS on Clover Creek. The estimated flow on June 6, 1996 in Chambers Creek at the outlet of Steilacoom Lake was 149 cfs and the calculated dissolved copper loading from the application on the previous day is 41.1 lbs/day. The dissolved copper load to Chambers Creek was a result of a treatment of 1,850 lbs of copper sulfate the previous day. In order to meet the load allocation of 0.0035 lbs/day, the treatment would have to be limited to 0.16 lbs/day. At the permitted application rate of 5 lbs/acre, the allocation would limit future treatment with copper sulfate to areas of 0.03 acres/day (1309 ft^2/day).

Seasonal Variation and Margin of Safety

Seasonal Variation

As mentioned in the above discussion, it is the total annual loading of phosphorus to Steilacoom Lake occurring throughout the entire year that needs to be controlled to address existing water quality problems. Accordingly, the TMDL establishes allocations for total annual loading and also includes a calculated maximum daily load. Potential seasonal variations in phosphorus loading should be considered when developing plans to reduce phosphorus entering Lake Steilacoom, but the reduction target needs to be total annual loading.

The TMDL also establishes allocations for copper when it is applied to control aquatic vegetation in the lake. These applications only occur during certain periods of the year and seasonal

variations in natural conditions or from other sources of loading is not an issue for loading considerations.

Margin of Safety

A margin of safety is inherit in the conservative assumptions used in developing this TMDL. For determining the copper allocation these assumptions include:

- using the critical low (7Q10) flow in Chambers Creek;
- the lower 5th percentile of hardness values measured (45.9 mg/L $CaCO_3$) was used to calculate the water quality standard for copper;
- the 90th percentile of monitored copper values were used as recommended by the Washington State Department of Ecology (1996).

The principle assumption contributing to the margin of safety for phosphorus is:

- a conservative estimate of natural background conditions. The lower quartile of phosphorus export coefficients found in the literature (Reckhow et al. 1980) for forests (0.019 kg/ha/yr) was applied to the 66.9 square mile Clover Creek watershed area for estimating pre-disturbance phosphorus loading. In other words, of the possible rates of phosphorus loading coming from forest lands, the 25 percentile(vs. a larger number) was used to represent natural loading conditions.

Future Implementation of the TMDL

For phosphorus

Absent a plan that addresses controlling all sources of phosphorus loading to the lake, implementation of the TMDL must be accomplished by using existing regulatory mechanisms. This means that water quality-based effluent limitations representing the loading allocations of this TMDL (see table 3a.) must be included in the existing NPDES permits for stormwater discharges from Pierce County and McChord AFB. The Pierce County stormwater permit requires that the implementing management plan be modified within four months of the establishment of a TMDL. The McChord AFB stormwater permit can be reopened at any time and reissued to include additional effluent limits based on the TMDL allocation. The City of Lakewood will receive a Phase II stormwater permit within the next four years that will include limitations necessary to meet allocations of the TMDL.

For Copper

Copper -based herbicide application to Steilacoom Lake cannot be permitted without Ecology issuing a short term modification of water quality standards. However, modifications cannot authorize discharges of pollutants (or applications of herbicides, in this case) which would cause

further degradation of water bodies that have been §303(d) listed for not meeting water quality standards. Also, modifications of standards cannot be issued to allow exceedence of the allocations established in an approved TMDL. Therefore, any future short term modification must be provisioned such that the copper allocation for Chambers Creek is not exceeded. As mentioned above, in order to meet the load allocation of 0.0035 lbs/day, copper-based herbicide treatment to Steilacoom Lake must be limited to 0.0035 lbs/day and at the permitted application rate of 5 lbs/acre, future treatments are limited to 0.16 acres/day.

Public Participation

On March 16, 1999, EPA public noticed the proposed TMDLs for Steilacoom Lake and Chambers Creek for phosphorus and copper respectively. A thirty day comment period was allowed. EPA's Responses to Comments is included as an attachment to this TMDL study. For further discussion of the public participation, see EPA's response to public comments regarding the public participation process.

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